# OPTIMIZED VACUUM BAGGING FOR CFRP ROCKET BOOSTER CASES

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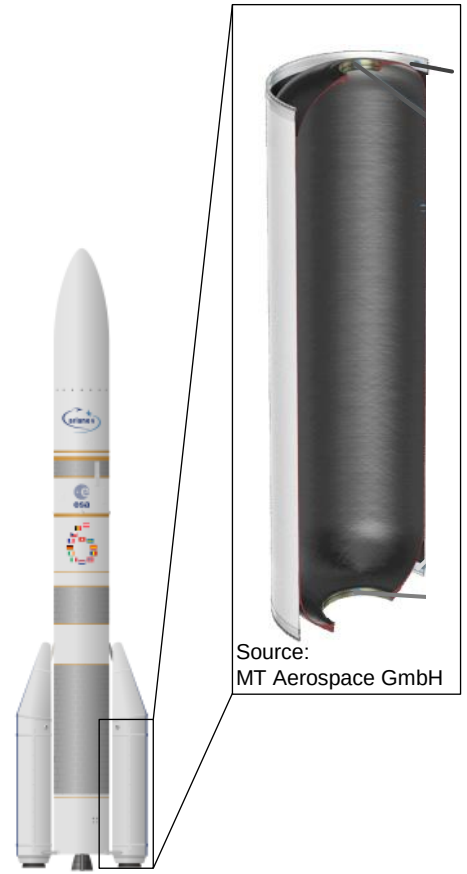
# Background

## Full-scale Ariane 6 Rocket Booster



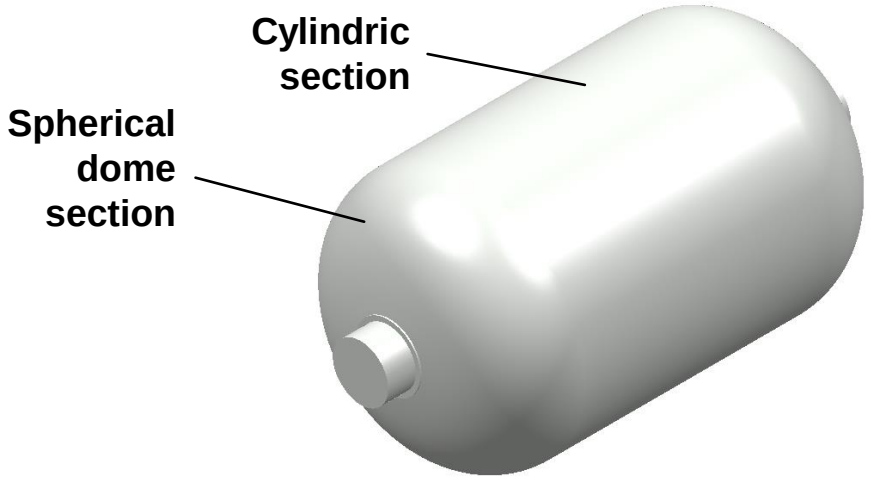
Source:
www.esa.int



Source:
MT Aerospace GmbH

- CFRP pressure tank + CFRP skirt with metallic interface ring
- Height: 12 m
- Diameter: 3.4 m
- Quantity: 17 / year

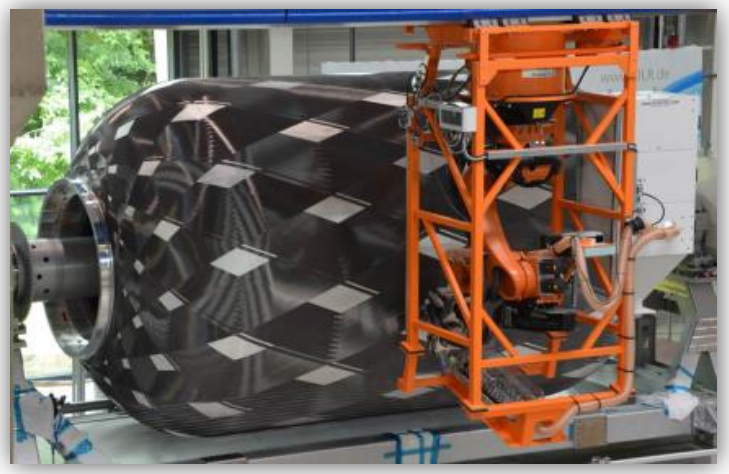
## Full-scale Demonstrator

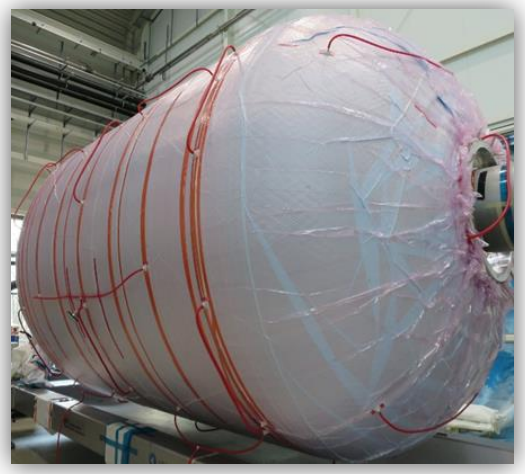



- Height: 6 m
- Diameter: 3.4 m

# Automated Booster Manufacturing Technologies

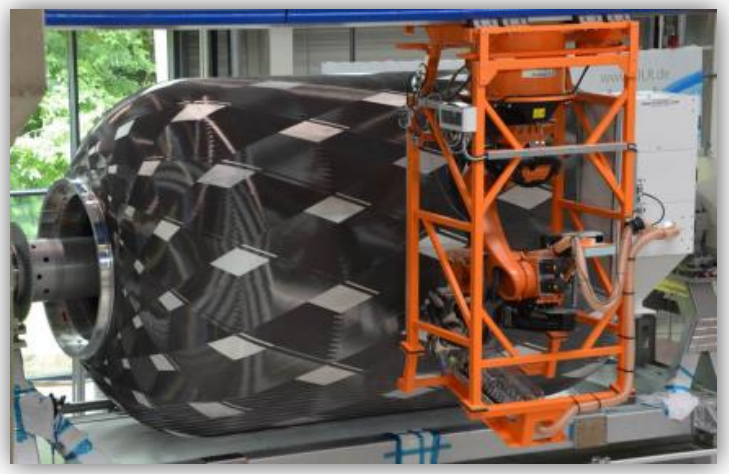
- Dry fiber preforming
- Vacuum bagging
- Liquid resin infusion
- Out-of-autoclave curing





# Automated Booster Manufacturing Technologies

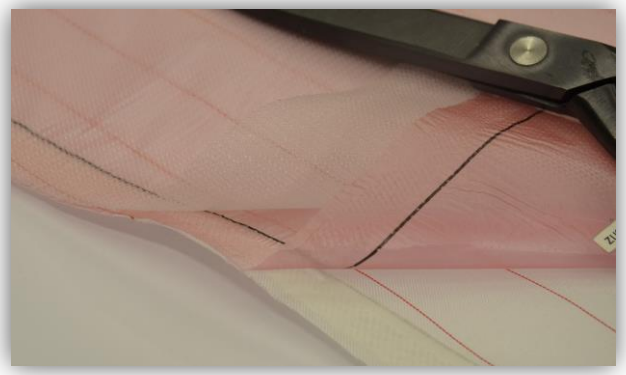
- Dry fiber preforming
- **Vacuum bagging**
- Liquid resin infusion
- Out-of-autoclave curing

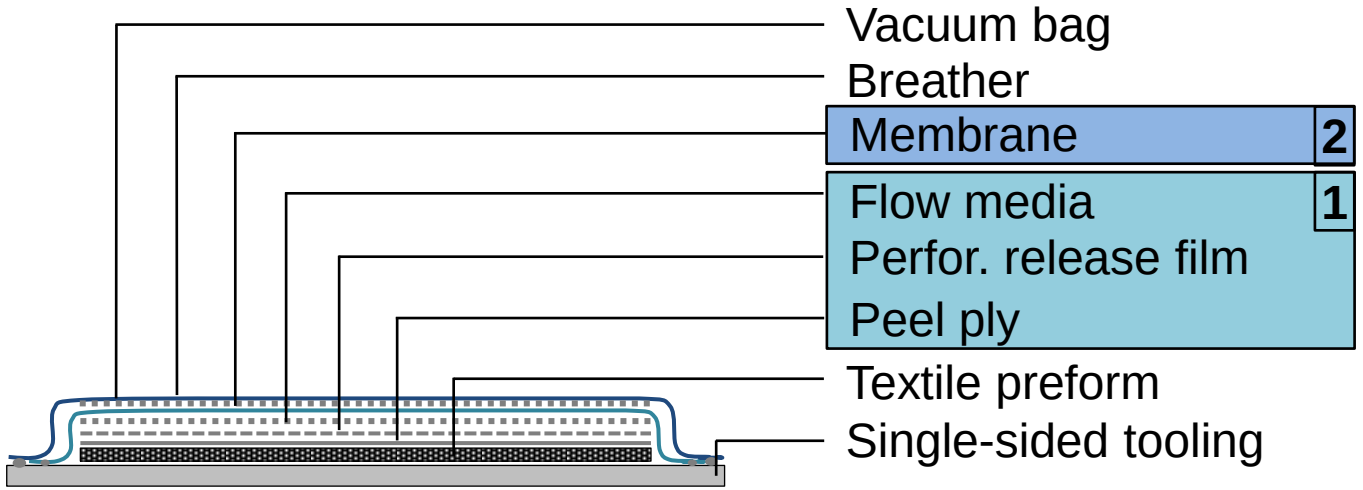


# Manufacturing Requirements

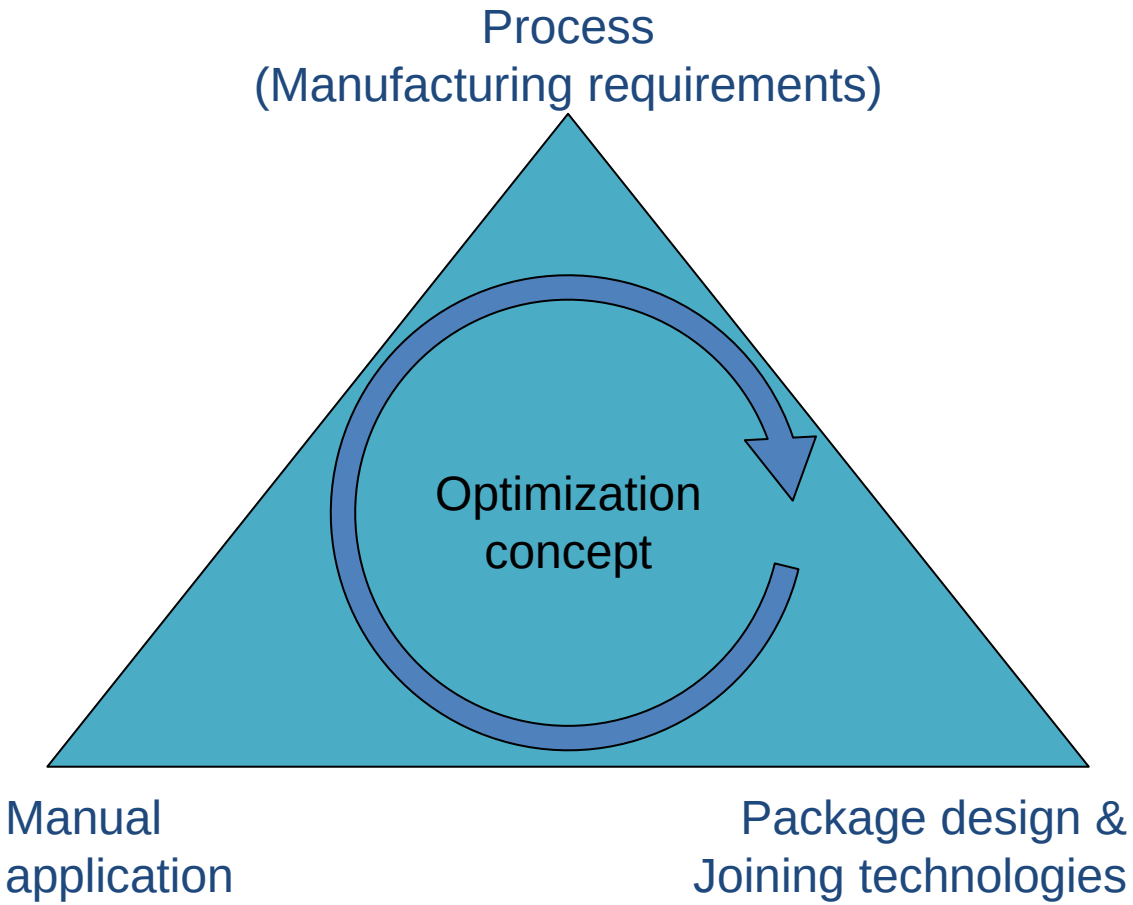
- Increase of reproducibility
  - → Reduced amount of wrinkles
  - → Reduced size of wrinkles
- Reduction of process steps on tooling
  - → Reduced variaties of ply design
- Compliance with gaps and overlaps

**Near net shape**
**auxiliary material packages**

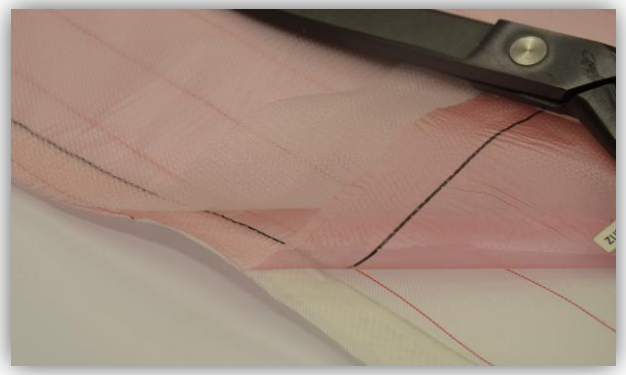


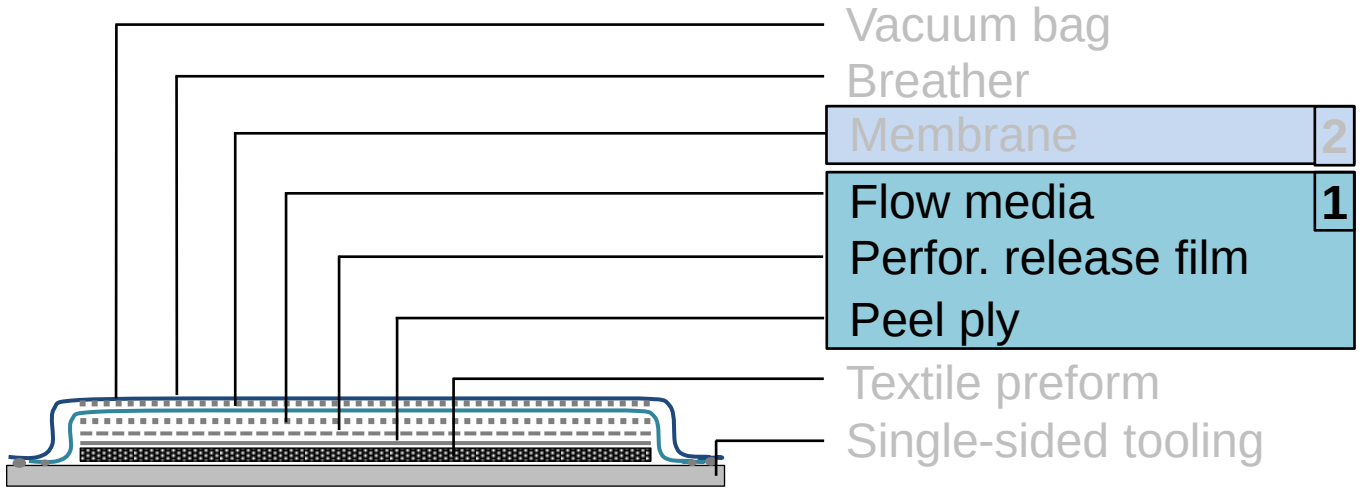


# Method and Approach



# Part 1 – Auxiliary Materials

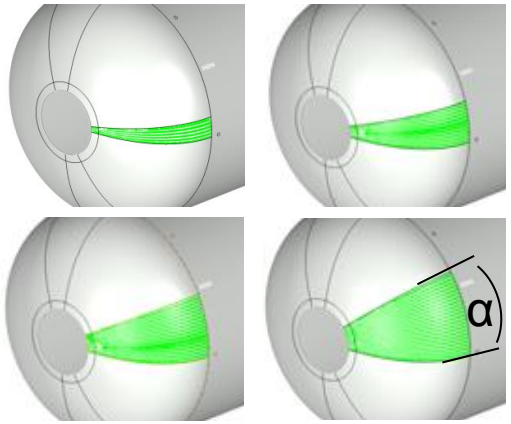




# Design Method – Peel Ply / Release Film / Flow Media

## 1. Step: Ply Design

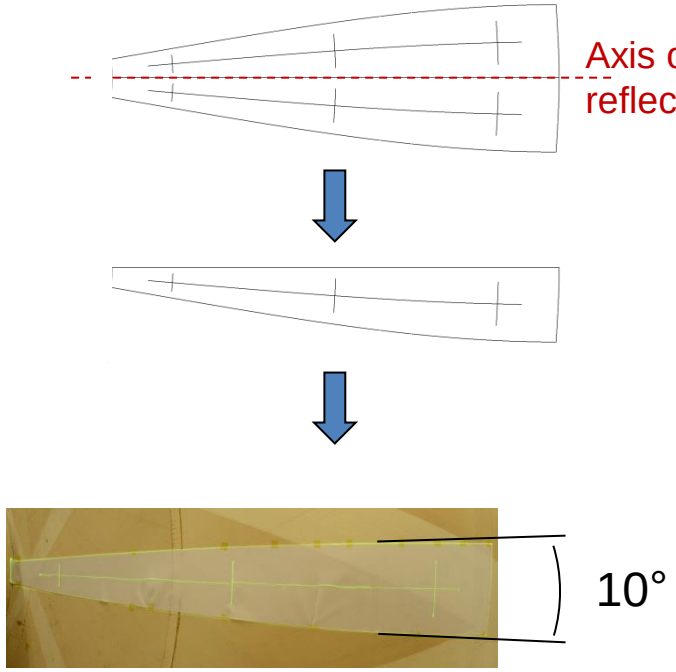
**α = ?**



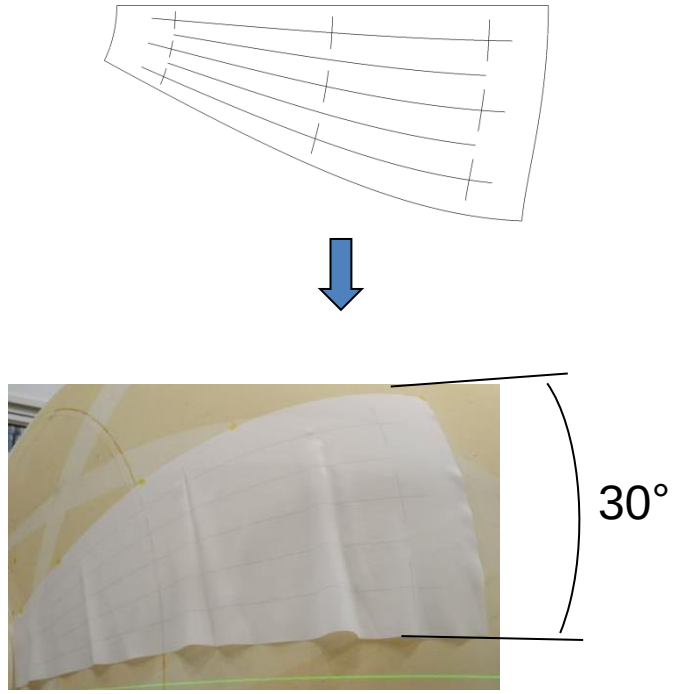

| $\alpha_{max}$: | vs. | $\alpha_{min}$: |
|---|---|---|
| reduced handling steps | | reduced amount of wrinkles |

## 2. Step: Evaluation of Angle α

**2a) α/2 = 10°**



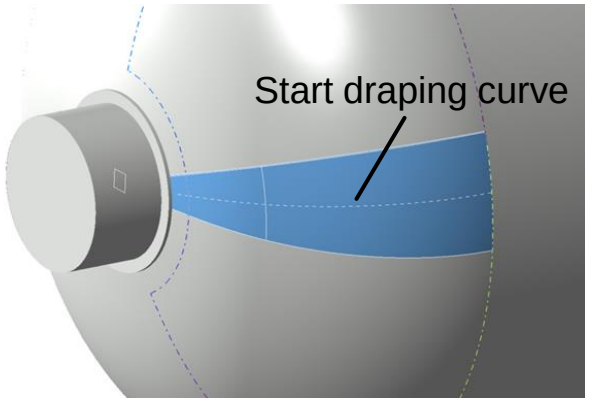

**2b) α/2 = 30°**




**α = 20°: Wrinkles < 20 mm**

# Design Method – Peel Ply / Release Film / Flow Media

## 3. Step: Final Geometry

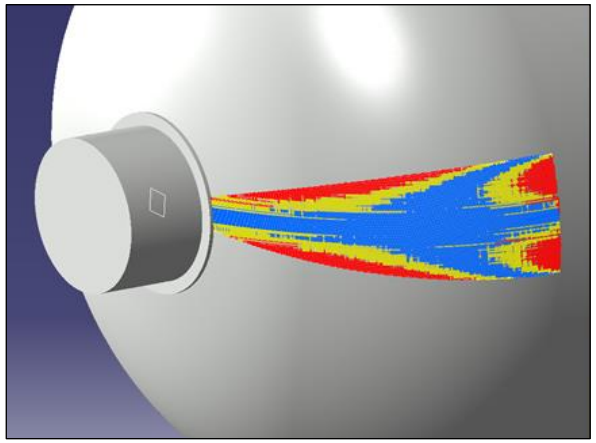



- 18 plies with α = 20°
- Length: 1715 mm
- Width: 610 mm

## 4. Step: Draping Simulation

Simulation parameters:

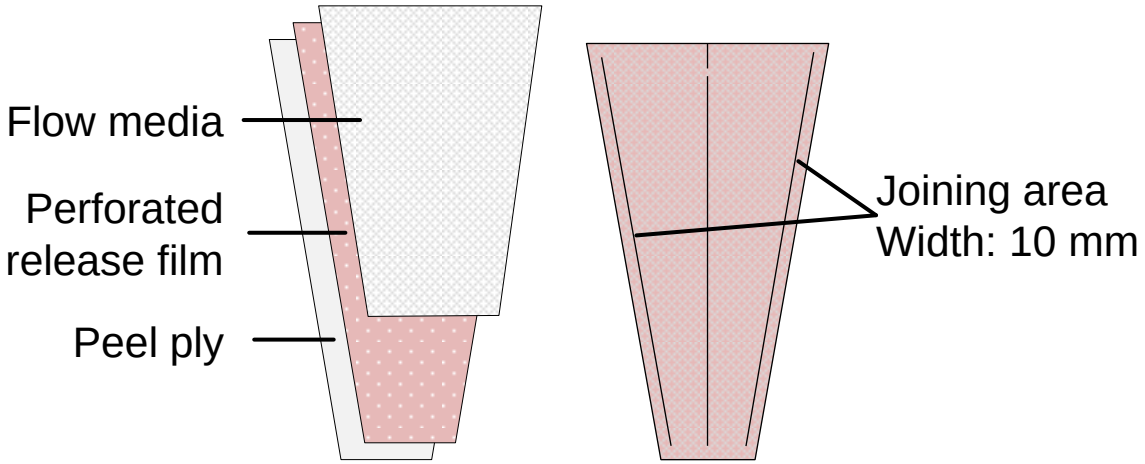
- Material draping properties
  → Planar isotropic
- Start conditions
  → Start draping curve = Axis of reflection



| | |
|---|---|
| Blue: | no distortion |
| Yellow: | light distortion |
| Red: | high distortion |

**→ Outcome: CAD file for cutting**

# Joining Technologies: Methods




<u>Sewing:</u>

- Reference joining technology

<u>Continuous Ultrasonic Welding:</u>

- Rotosonic V4E, Nucleus GmbH
- Feed rate: 0.8 m/min
- Rolling sonotrode
- Anviel-wheel with shaded or punctated profile

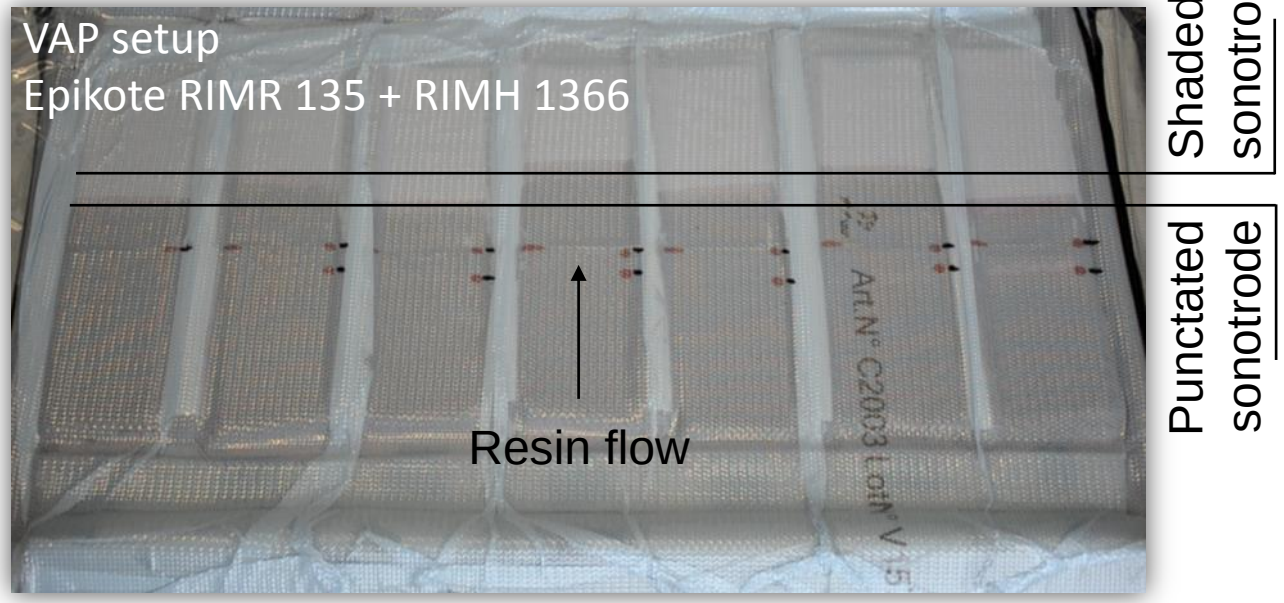
Source: Nucleus GmbH

# Joining Technologies: Test procedure

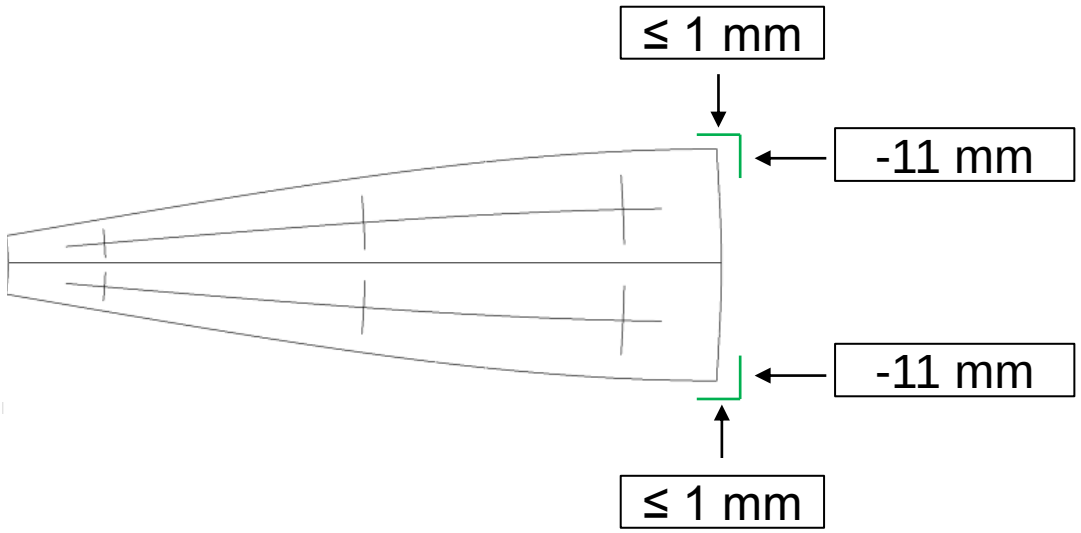
## Charcteristics:

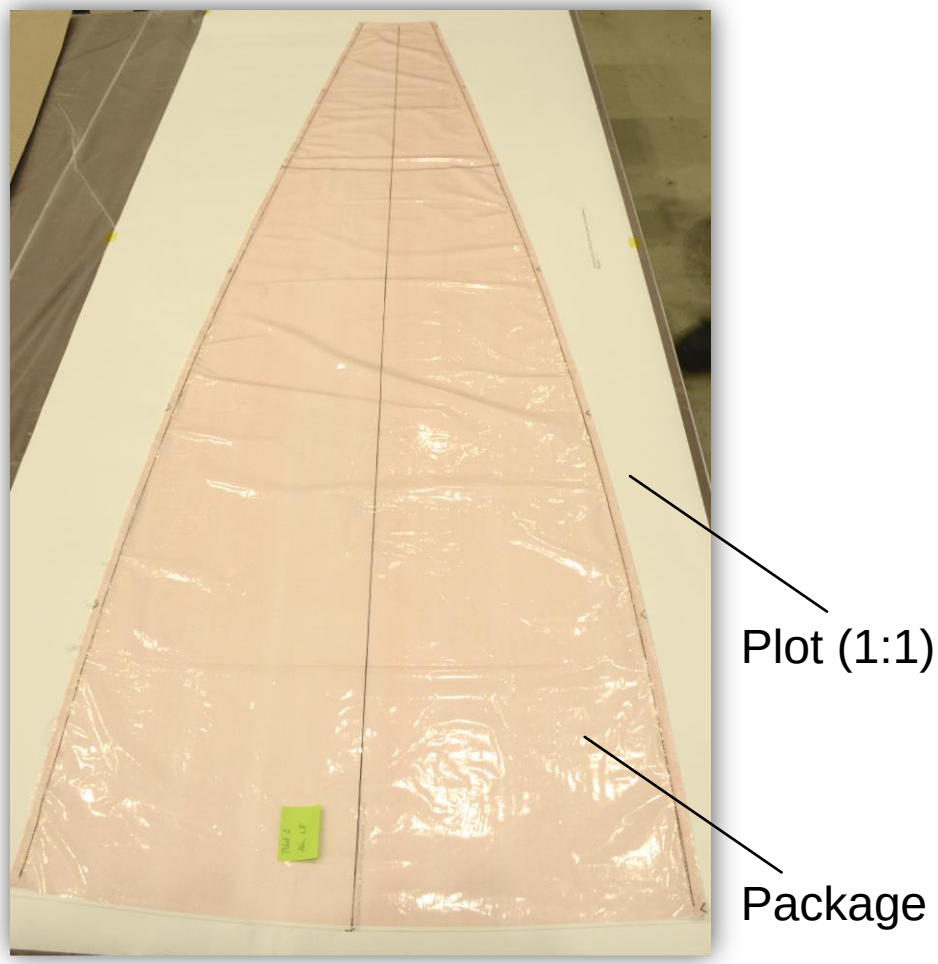
- Barrier for resin flow
- Damage of auxiliary materials
- Imprints on part surface
  (seam: approx. 0.35 mm)
- Decrease of flexibility/ drapability

## Resin flow propagation:



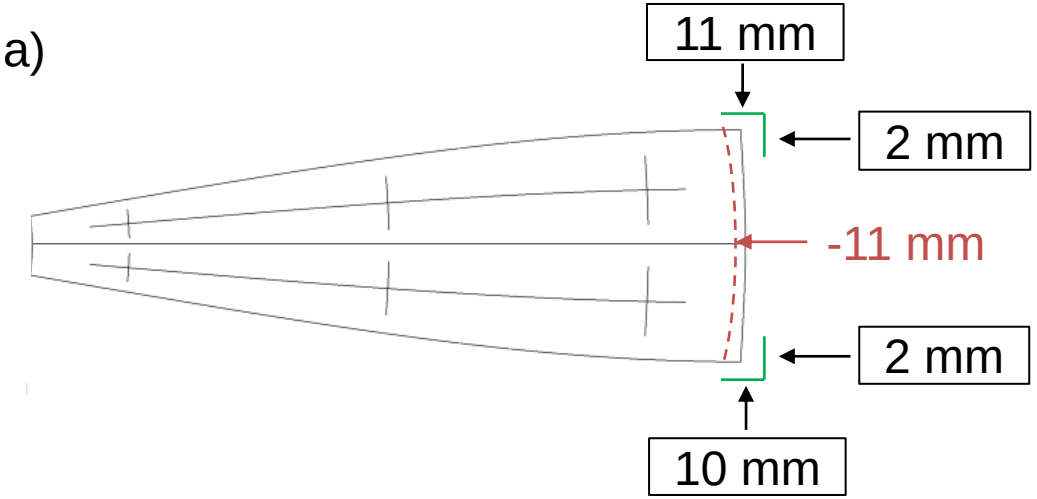
# Manual Application Test – 2D-Check of Packages

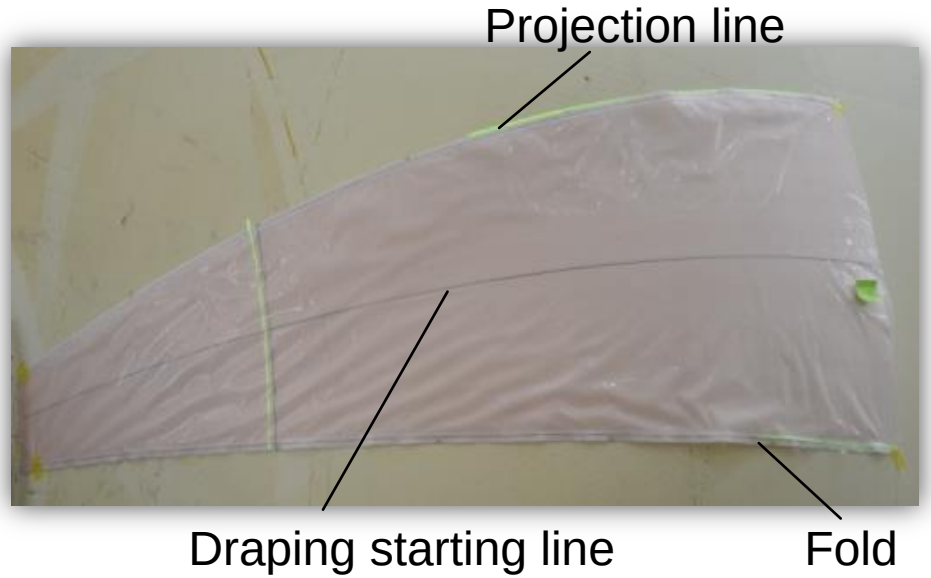


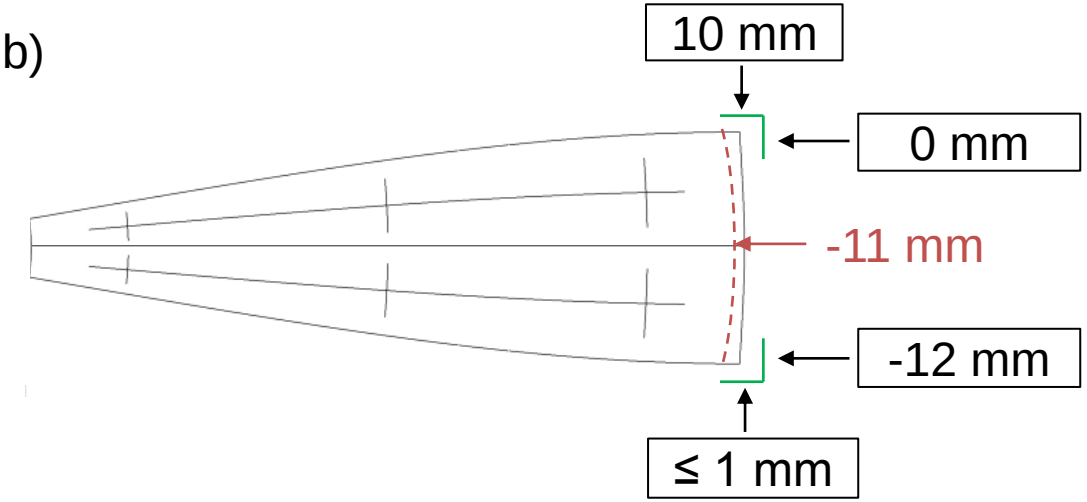
# Manual Application Test – 3D-Check of Packages

Test a)

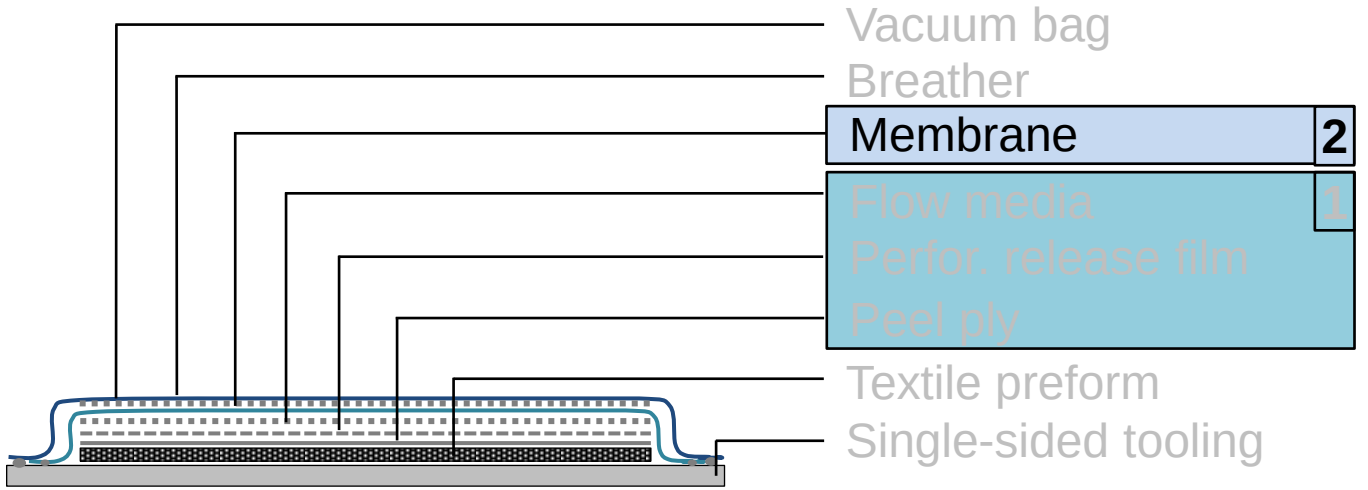



Test b)



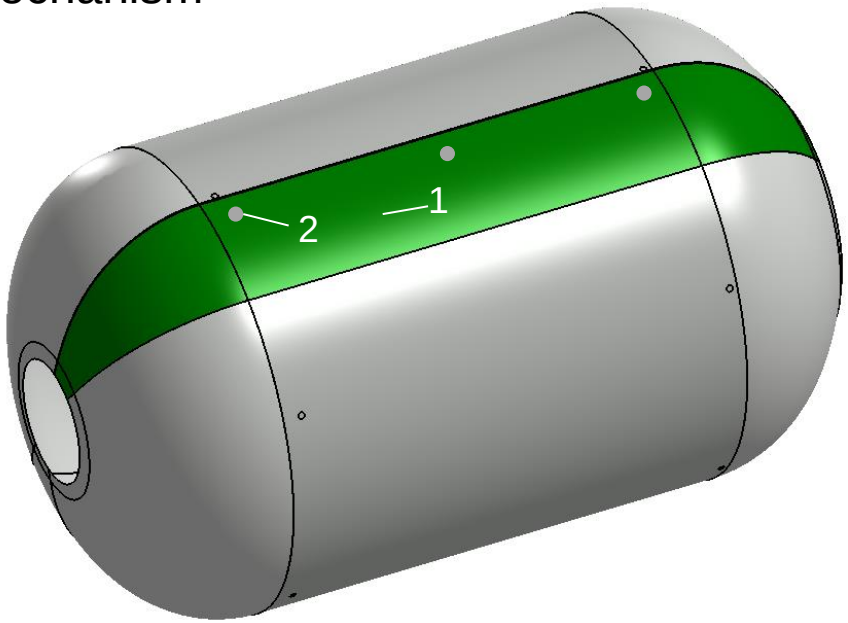

# Part 2 – Membrane



# Design Method – Membrane

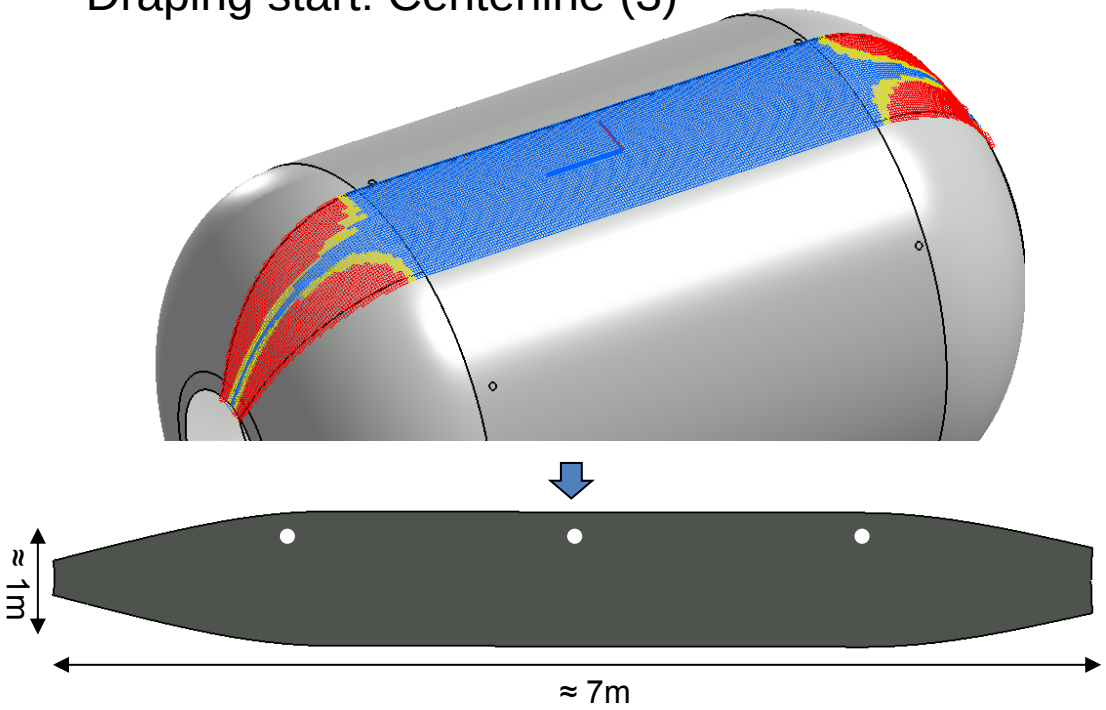
## 1. Step: Single ply design

- Rotationally symmetrical ply (1)
- Use Case: 12 plies (Width ≈ 1m; Length ≈ 7m)
- Holes (2) at resin inlets for application mechanism




## 2. Step: Unfolding of ply

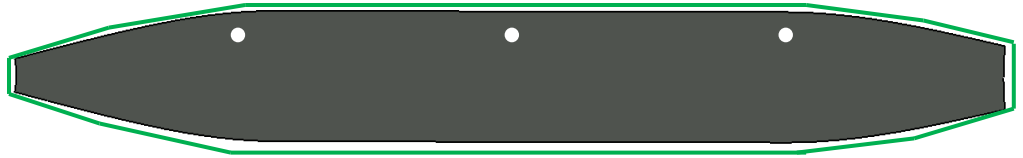
- Membrane represented as 0°/90° textile fabric (CATIA)
- Draping start: Centerline (3)



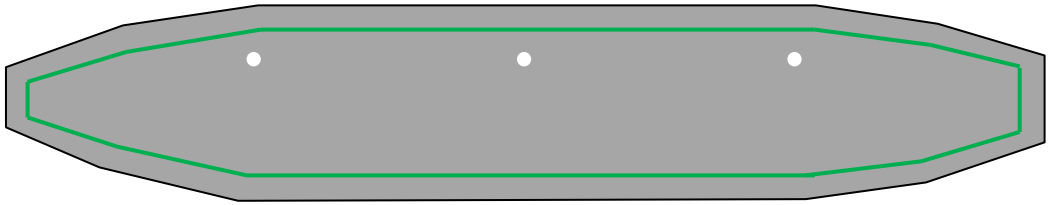
# Design Method – Membrane

## 3. Step: Adjustment of edges

- Linearization of the edges for a better joining

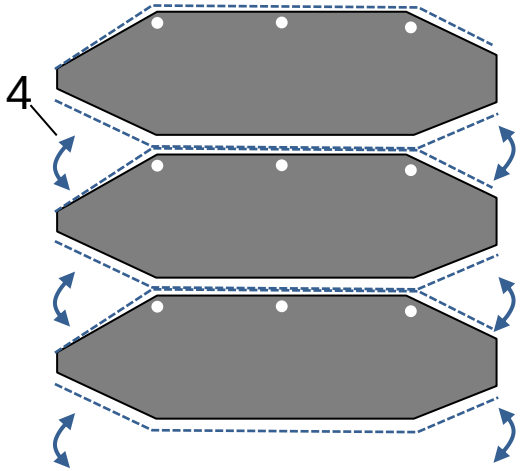


- Additional material for a joining with tacky tape



## 4. Step: Manufacturing of entire setup

- Cutting of all single plies
- Joining of the plies with tacky tape
- Joining (4) creates the 3D-tailoring of the membrane



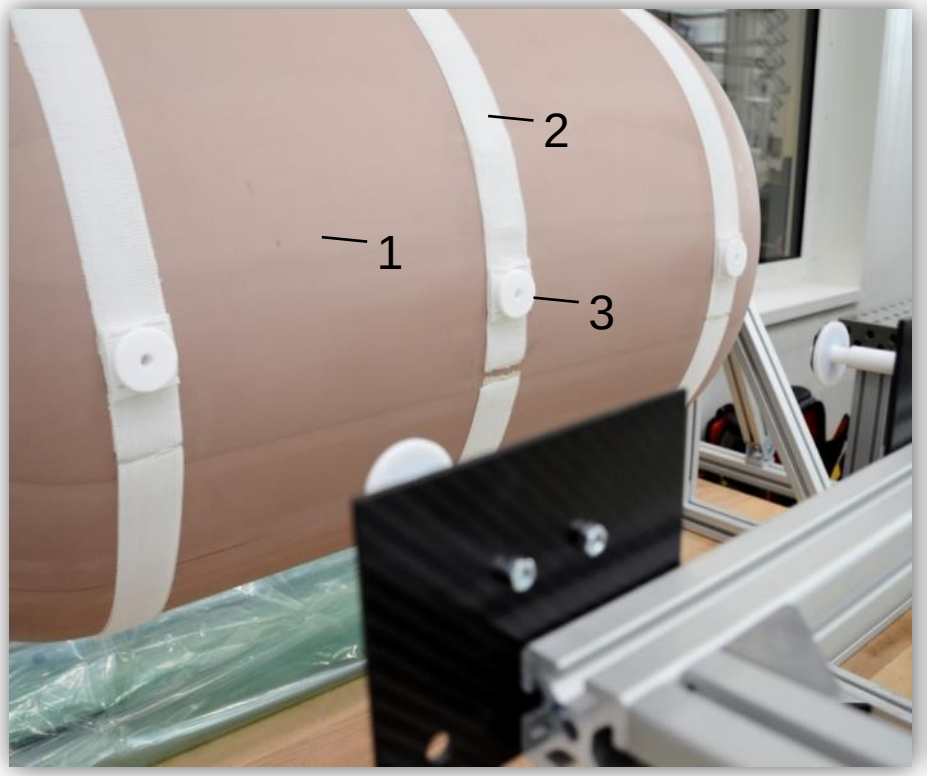

# Basic Application Mechanism

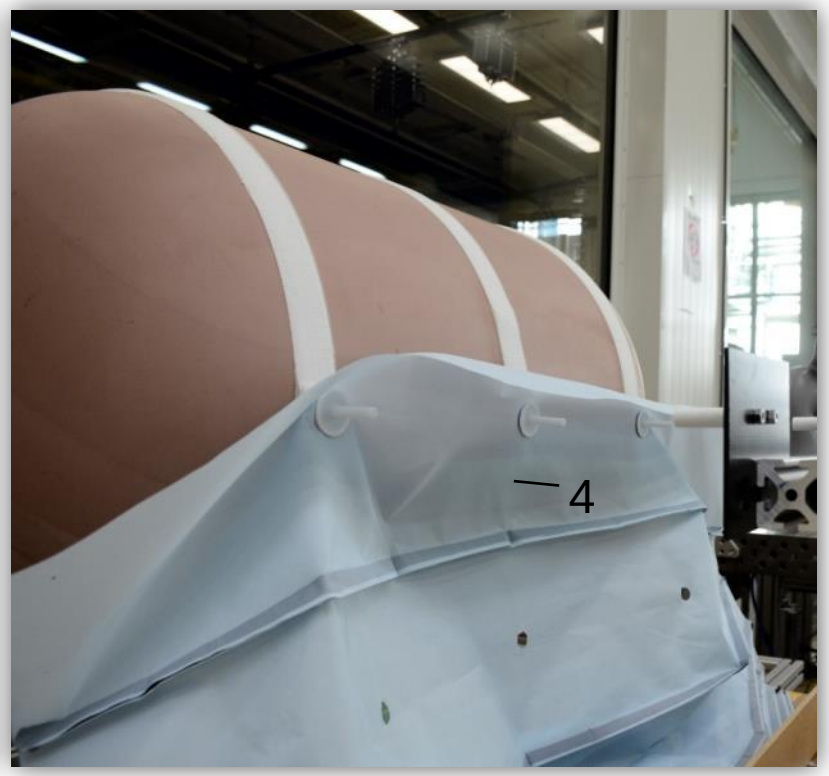
(1) Scaled model of the booster geometry (scale: 1:6)

(2) Resin infusion chanels

(3) Resin inlets

(4) Tailored Membrane



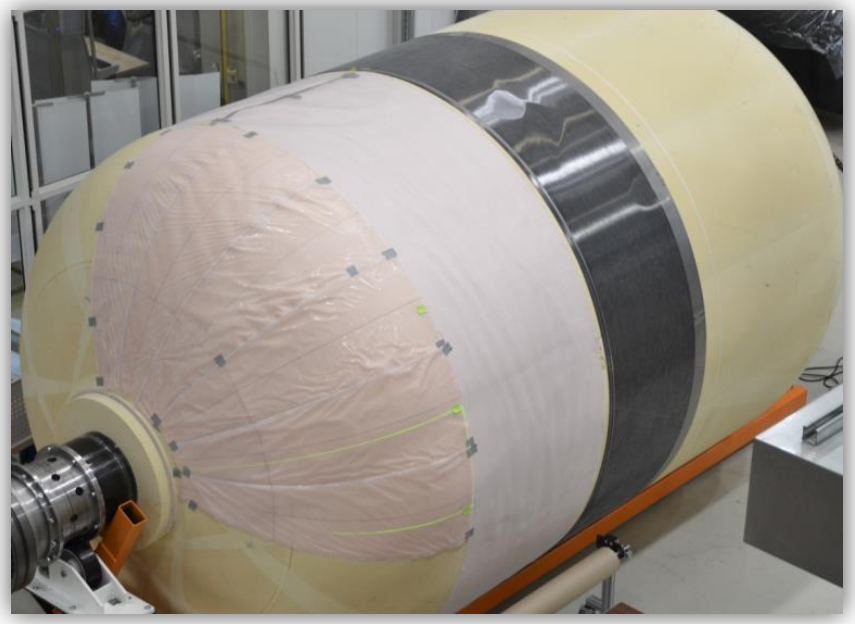
# Application Concept


## Advantages

- Usage of pre-positioned resin inlets
  → precise placement
- Usage of tooling rotation
  → no additional infrastructure neccesary
- Reproducible application method
  →Increased quality insurance

**Video**

# Summary and Outlook




**Results:**

- Developement of a design method for auxiliary materials
- Evaluation of Joining Technologies
- Verification of taylored materials on full-scale demonstrator

**Future investigations:**

- Development of a robotic application system
- Comparison: manual handling vs. automated handling


Thank you!
Thanks to my colleagues at DLR
as well as to our partners from
MT Aerospace and Trans-Textil!
DLR
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